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Bibliography on

The Analyses of Optical Atomic Spectra Section 4

^{57}La – ^{71}Lu

^{89}Ac – ^{99}Es

NAT'L INST. OF STAND & TECH R.I.C.



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UNITED STATES DEPARTMENT OF COMMERCE

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NATIONAL BUREAU OF STANDARDS • A. V. Astin, *Director*

Bibliography on The Analyses of Optical Atomic Spectra Section 4

The Spectra of Lanthanum, Cerium, Praseodymium, Neodymium,
Promethium, Samarium, Europium, Gadolinium, Terbium,
Dysprosium, Holmium, Erbium, Thulium, Ytterbium, Lutetium—
Actinium, Thorium, Protactinium, Uranium, Neptunium,
Plutonium, Americium, Curium, Berkelium, Californium, and
Einsteinium

Charlotte E. Moore

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Preface

The program on "Atomic Energy Levels" (AEL) initiated at this Bureau in 1946 calls for complete coverage of the Periodic Table. Three Volumes have been published as NBS Circular 467. The fourth volume deals with rare-earth spectra and is in course of preparation.

The references to individual spectra have been extended from the respective dates of publication of the AEL Volumes, 1949, 1952, and 1958, in the first three corresponding Sections of this bibliography.

The present and last Section contains references to the two groups of rare-earth spectra, the lanthanides and the actinides. It is arranged to correspond to AEL Volume IV, but it differs from the first three Sections in that it does not continue references from a published volume.

Upon the retirement of the author, Charlotte E. Moore, who has been directing this program, the responsibility for continuing it was assigned to William C. Martin, Chief of the Spectroscopy Section of the Bureau, assisted by Lucy Hagan. He is in charge of the preparation of AEL Volume IV. Publication is being delayed because many of the spectra to be included are still under active investigation.

DAVID R. LIDE, JR., *Chief*
Office of Standard Reference Data.

Abstract

There is a steady demand for information on rare-earth spectra. In an attempt to satisfy this need the present bibliography has been prepared. It comprises Section 4, concludes this publication, and completes the coverage of the Periodic Table. The references listed have been selected on a general basis as those needed for the preparation of Volume 4 of "Atomic Energy Levels."

Since rare-earth structure is revealed in the neighboring spectra, ^{57}La and ^{89}Ac , the references for these elements are repeated in the present Section, which contains the two groups of elements:

^{57}La to ^{71}Lu and ^{89}Ac to ^{99}Es

A selected list of general literature references is also included.

Nearly all of the quoted references have been checked from the original papers.

Key words: Analyses of rare-earth spectra; atomic spectra,
La through Lu, Ac through Es;
references to atomic spectra; rare-earth spectra;
spectra, atomic: elements, spectra of rare-earths.

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Bibliography on The Analyses of Optical Atomic Spectra

Charlotte E. Moore

The present bibliography concludes the series of which three Sections have been published; Section 1 in September 1968, Section 2 in February 1969, and Section 3 in May 1969. Each of these three Sections covers the same elements as are contained in the respective three Volumes of "Atomic Energy Levels" [1]:¹

Section 1	¹ H through ²³ V
Section 2	²⁴ Cr through ⁴¹ Nb
Section 3	$\left\{ \begin{array}{l} ^{42} \text{Mo through } ^{57} \text{La} \\ ^{72} \text{Hf through } ^{89} \text{Ac} \end{array} \right.$

The earlier references to the spectra of these elements are contained in "Atomic Energy Levels," and the various Sections of this publication provide references on individual spectra from the respective dates of publication of the three Volumes to the present.

The fourth Volume of the Atomic Energy Levels Series will contain the rare-earth elements, and thus complete the coverage of the Periodic Table. Many of the very complex spectra to be included are still under active investigation. Pending further progress toward the preparation of this Volume, the present bibliography has been prepared with the hope that it will satisfy to some extent the continuing demand for information on rare-earth spectra.

As in the preceding Sections the content of the individual papers is briefly described by key letters or words. The letters have the following meanings:

C L	Classified lines
E D	Energy level diagram
G D	Grotrian diagram
I P	Ionization potential
I S	Isotope shift
T	Terms (and/or energy levels)
W L	Wavelength
Z E	Zeeman effect
[]	Forbidden transitions
hfs	Hyperfine structure

¹ Figures in brackets indicate the literature references on page VIII.

If the paper is an Abstract or a Letter to the Editor, the respective letters "A" and "L" are entered in parentheses before the date of the reference.

The author has published partial reference lists for rare-earth spectra, most of which are embodied in the present Section [2, 3, 4]. The list of references has been greatly extended, but is selective. In general, an effort has been made to include all references to date that are needed to compile tables of atomic energy levels, classified lines and Zeeman data for rare-earth spectra [5]. The selection is essentially similar to that of the former Sections, but differs in that it is not a continuation from those included in a Volume of "Atomic Energy Levels" already published.

A number of criteria contribute to the interpretation of these complex spectra. In preparing the bibliography the writer has attempted to recognize the importance of references to theoretical papers and to work on hyperfine structure, isotope shift and other related subjects. Here the listing is not complete, but it is hoped that enough is given to serve as a guide to further references in the various fields.

Many rare-earth spectra are being observed in crystals and solutions, as absorption or fluorescence spectra. A number of lists of energy levels derived from these spectra have been published for individual spectra. This is a separate subject in itself, however; it is not covered in the present work, which is limited essentially to work on "the analyses of optical spectra."

The characteristic that distinguishes rare-earth spectra is the presence of *f*-electrons in the outer structure of the atoms, namely 4*f*-electrons for the lanthanon group ⁵⁸Ce to ⁷¹Lu, and 5*f*-electrons for the actinon group ⁹⁰Th to ¹⁰³Lw. The elements preceding each of these groups, ⁵⁷La and ⁸⁹Ac, begin to reveal in their spectra some rare-earth characteristics, and thus provide a useful introduction to the study of rare-earth spectra. Consequently, the references to spectra of these two elements as given in Section 3 are repeated in Section 4.

The references are arranged similarly to those in the earlier Sections. They are with few exceptions, arranged in alphabetical order by author and by year for a given spectrum, starting with the earlier papers. A list of general references precedes the main Bibliography.

Nearly all of the references quoted here have been verified by the author. Only a very few which were not available have been copied from abstracts found in the literature.

The author appreciates the generosity of all who have contributed material for inclusion here. A number of colleagues have made special effort to furnish current references and reprints. W. C. Martin and his staff in the Spectroscopy Section have carefully examined the manuscript and given her the benefit of their experience with references to rare-earth spectra.

This Special Publication could not have been prepared without the continuing and efficient cooperation of Elizabeth L. Tate and her competent staff in the splendid Library of the National Bureau of Standards. Their help has been invaluable. Similarly, the preparation of the press copy of the manuscript with extreme care has been carried out by Isabel D. Murray. The author is most grateful for this splendid assistance.

References

- [1] C. E. Moore, Circ. Nat. Bur. Std. 467, Vol. **I**, 309 pp. (1949); Vol. **II**, 227 pp. (1952); Vol. **III**, 245 pp. (1958).
- [2] C. E. Moore, Circ. Nat. Bur. Std. 467, Vol. **III**, xxxiii (1958).
- [3] C. E. Moore, Applied Optics **2**, 665 to 674 (1963).
- [4] W. F. Meggers and C. E. Moore, Trans. Joint Comm. for Spectroscopy, J. Opt. Soc. Am. **47**, 1035 to 1041 (1957); **50**, 405 to 407 (1960); **52**, 583 to 584 (1962); **53**, 885 to 889 (1963).
- [5] C. E. Moore, Reprinting of 1945 Princeton Multiplet Table, Nat. Bur. Std. Tech. Note 36, PB151395, 245 pp. (1959).

WASHINGTON, D.C., March 10, 1969.

General References

- L. Rolla and G. Piccardi, Phil. Mag. [7] 7, 286 to 301 (1929). Experimental I P First Spectra Lanthanides
- W. F. Meggers, Rev. Mod. Phys. 14, 96 to 103 (1942). Review "Atomic Spectra of Rare-Earth Elements"
- PH. Schuurmans, Physica 12, 589 to 594 (1946). Low Configurations in Rare-Earth Spectra
- L. F. H. Bovey, Nature 177, 737 to 738 (1956). Argonne Symposium Review Atomic Spectroscopy
- I. N. Bakulina a N. I. Ionov, Zh. Eks. Teor. Fiz., U.S.S.R. 36, 1001 to 1005 (1959). Experimental I P: U I
- N. I. Ionov a M. A. Mittsev, Zh. Eks. Teor. Fiz., U.S.S.R. 38, 1350 to 1351 (1960). Experimental I P: Pr I, Nd I
- G. Racah, J. Opt. Soc. Am. 50, 408 to 411 (1960). Notation
- A. Y. Cabezas, I. Lindgren and R. Marrus, Phys. Rev. 122, 1796 to 1801 (1961). Atomic Beam Investigations, Z E Ground States
- J. B. Gruber and J. G. Conway, J. Chem. Phys. 34, 632 to 638 (1961). Theory f^6 Configurations Rare-Earth Ions
- N. I. Ionov a M. A. Mittsev, Zh. Eks. Teor. Fiz., U.S.S.R. 40, 741 to 742 (1961). Experimental I P: Er I, Tb I, Ce I, Th I
- B. R. Judd and I. Lindgren, Phys. Rev. 122, 1802 to 1812 (1961). Theory Z E in Ground Multiplets
- J. Sugar, J. Research Nat. Bur. Std. 66A, 321 to 324 (1962). Self-reversed Lines
- B. G. Wybourne, J. Chem. Phys. 36, 2295 to 2300, 2301 to 2311 (1962). Theory f^n Configurations, Trivalent Rare-Earth Ions
- J. G. Conway and B. G. Wybourne, Phys. Rev. 130, 2325 to 2332 (1963). Theory, Low-Lying Energy Levels of Lanthanide Atoms
- C. E. Moore, Appl. Opt. 2, 665 to 674 (1963). Bibliography
- V. G. Mossotti and V. A. Fassel, Spectrochim. Acta 20, 1117 to 1127 (1964). Absorption Spectra Lanthanide Elements
- J. G. Conway, J. Chem. Phys. 41, 904 to 905 (L) (1964). Theory Energy Levels in 4^+ Actinides

General References — Continued

- J. Sugar and J. Reader, J. Opt. Soc. Am. 55, 1286 to 1290 (1965). I P
Singly-Ionized Rare-Earths
- B. G. Wybourne, "Spectroscopic Properties of the Rare Earths", 236 pp.,
Interscience Publishers, New York (1965).
- J. Reader and J. Sugar, J. Opt. Soc. Am. 56, 1189 to 1194 (1966). I P
Neutral Rare-Earths
- S. D. Dey and S. B. Karmohapatro, Proc. 1st Intern. Conf. Spectr.
(Bombay) 1, 38 to 41 (1967). Experimental I P Rare-Earth Spectra:
Pr 1, Gd 1, Dy 1, Ho 1, Er 1
- G. H. Dieke, "Optical Properties of Ions in Crystals" 552 pp.,
H. M. Crosswhite and H. W. Moos, Editors, Interscience Publishers,
New York (1967).
- Z. B. Goldschmidt, Dept. of Theoretical Physics, The Hebrew University,
Jerusalem, Israel, Properties and Methods of Interpretation of Rare-
Earth Spectra, 39 pp. (1967); "Spectroscopic and Group Theoretical
Methods in Physics", F. Bloch etc., Editors, pp. 411 to 457 (John Wiley
and Sons, New York, 1968).
- J. Blaise und A. Steudel, Zeit. Phys. 209, 311 to 328 (1968). I S
- F. Bloch, S. G. Cohen, A. De-Shalit, S. Sambursky, I. Talmi, Editors,
"Spectroscopic and Group Theoretical Methods in Physics", Racah
Memorial Volume, 462 pp. (John Wiley and Sons, Inc., New York; North
Holland Publishing Company, Amsterdam, 1968). Theory
- W. T. Carnall, P. R. Fields and K. Rajnak, J. Chem. Phys. 49, 4412 to
4455 (1968). Energy Levels in Trivalent Lanthanide Aquo Ions, Theory
- B. R. Judd, H. M. Crosswhite and H. Crosswhite, Phys. Rev. 169, 130 to
138 (1968). Theory, "Intra-Atomic Magnetic Interactions for
f Electrons". Ce III, Pr IV, Pm I, Gd IV

LANTHANUM (Z = 57)

La I

- C. E. Moore and P. W. Merrill, Appendix A: Partial Grotrian Diagrams (1956); Nat. Std. Ref. Data Series, Nat. Bur. Std. NSRDS-NBS 23, 43 (1968). C L
- R. A. Fisher, W. C. Knopf, Jr., F. E. Kinney, Astroph. J. 130, 683 to 687 (1959). W L, C L Infrared
- K. Murakawa, J. Phys. Soc. Japan 16, 2533 to 2537 (1961). hfs
- V. G. Mossotti and V. A. Fassel, Spectrochim. Acta 20, 117 to 127 (1964). C L Absorption Lines
- W. R. S. Garton and M. Wilson, Astroph. J. 145, 333 to 336 (1966). I P, E D, Series Autoionization
- N. Spector, unpublished material (June 1966). T
- J. Stein, J. Opt. Soc. Am. 57, 333 to 335 (1967). T, Z E Theory
- W. J. Childs and L. S. Goodman, Bull. Am. Phys. Soc. [2] 13, 20, 891 to 892 (1968). hfs, Z E
- A. Giacchetti and M. Wilson, J. Opt. Soc. Am. 58, 740 (A) (1968). Analysis in progress

La II

- C. E. Moore and P. W. Merrill, Appendix A: Partial Grotrian Diagrams (1956); Nat. Std. Ref. Data Series, Nat. Bur. Std. NSRDS-NBS 23, 41 (1968). C L
- K. Murakawa, Phys. Rev. 110, 393 to 396 (1958). hfs
- J. Sugar and J. Reader, J. Opt. Soc. Am. 55, 1286 to 1290 (1965). I P

La III

- J. Sugar and V. Kaufman, J. Opt. Soc. Am. 55, 1283 to 1285 (1965). I P, T, C L
- H. Odabasi, J. Opt. Soc. Am. 57, 1459 to 1463 (1967). I P, T, C L, G D, W L

CERIUM (Z = 58)

Ce I

- A. S. King, *Astroph. J.* 68, 194 to 219 (1928). Temperature Classification
- F. W. Paul, *Phys. Rev.* 49, 156 to 162 (1936). W L Absorption
- H. J. van de Vliet, Dissertation, Univ. Amsterdam, p. 69 (N. V. Noord-Hollandsche Uitgevers Maatschappij, Amsterdam) (1939). Z E
- K. F. Smith and I. J. Spalding, *Proc. Roy. Soc. London* A265, 133 to 140 (1961). Z E Atomic Beam
- W. C. Martin, *J. Opt. Soc. Am.* 53, 1047 to 1050 (1963). T, Z E
- R.-J. Champeau, S. Gerstenkorn et G. Glück, *Compt. Rend.* 262B, 1429 to 1431 (1966). I S
- S. Gerstenkorn, unpublished material (1966). Near Infrared Observations 0.8 μ to 2.5 μ
- J. Reader and J. Sugar, *J. Opt. Soc. Am.* 56, 1189 to 1194 (1966). I P
- Z. B. Goldschmidt and D. Salomon, Program Atomic Sp. Symposium, Nat. Bur. Std., p. 77 (A) (September 1967). Theory
- W. C. Martin, Program Atomic Sp. Symposium, Nat. Bur. Std., p. 78 (A) (September 1967). T, Configurations
- R. J. Champeau et S. Gerstenkorn, *Phys. Lett. (Amsterdam)* 26A, 334 to 335 (1968). I S
- W. C. Martin, Analysis in progress (1969).
- W. C. Martin, C. H. Corliss and M. Wilson, unpublished material (1969). W L

Ce II

- A. S. King, *Astroph. J.* 68, 194 to 219 (1928). Temperature Classification
- W. E. Albertson and G. R. Harrison, *Phys. Rev.* 52, 1209 to 1215 (1937). T, C L
- G. R. Harrison and W. E. Albertson, *Phys. Rev.* 53, 940 to 941 (A) (1938). Analysis extended

CERIUM

Ce II - Continued

- F. M. Gerasimov, Zh. Eks. Teor. Fiz., U.S.S.R. 9, 1036 to 1048 (1939).
Z E, C L
- H. J. van de Vliet, Dissertation, Univ. Amsterdam, pp. 43 to 68
(N. V. Noord-Hollandsche Uitgevers Maatschappij, Amsterdam)(1939). Z E
- G. R. Harrison, W. E. Albertson and N. F. Hosford, J. Opt. Soc. Am. 31,
439 to 448 (1941). T, C L, Z E
- PH. Schuurmans, Dissertation, Univ. Amsterdam, pp. 34 to 36 (1946);
Physica 12, 589 to 594 (1946). T, C L, Z E, hfs
- W. E. Albertson, unpublished material (1949) (1955). T, C L
- P. Brix und H. Frank, Zeit. Phys. 127, 289 to 296 (1950). I S
- K. Murakawa and J. S. Ross, Phys. Rev. 83, 1272 to 1273 (L) (1951). I S
- H. Arroe, Phys. Rev. 93, 94 (1954). I S
- G. Racah, Bull. Research Council Israel 5A, 78 (1955). T
- L. A. Korostyleva, Opt. i Spektr. 3, 536 to 544 (1957). I S
- G. Racah, unpublished material (1959). T, C L
- J. Sugar and J. Reader, J. Opt. Soc. Am. 55, 1286 to 1290 (1965). I P
- Z. B. Goldschmidt, On program at The Hebrew University, Jerusalem (1969).
Analysis being extended, Theory
- W. C. Martin and C. H. Corliss, unpublished material (1969). W L

Ce III

- A. S. King and R. B. King, Astroph. J. 75, 40 to 45 (1932). W L
- T. L. de Bruin, J. N. Lier and H. J. van de Vliet, Proc. Kon. Nederl.
Akad. Wetensch. 40, 334 to 339 (1937). Z E, T, C L
- H. N. Russell, R. B. King and R. J. Lang, Phys. Rev. 52, 456 to 466
(1937). I P, T, C L, Z E
- F. M. Gerasimov, Zh. Eks. Teor. Fiz., U.S.S.R. 9, 1036 to 1048 (1939).
Z E

CERIUM

Ce III - Continued

- H. J. van de Vliet, Dissertation, Univ. Amsterdam, pp. 30 to 41
(N. V. Noord-Hollandsche Uitgevers Maatschappij, Amsterdam)(1939). Z E
- N. Spector, J. Opt. Soc. Am. 55, 492 to 501 (1965). Theory
4f nl Configurations
- J. Sugar, J. Opt. Soc. Am. 55, 33 to 58 (1965). I P, T, C L, E D
- Z. B. Goldschmidt, Colloq. Intern. Centre Nat. Rech. Sci. (Paris)
No. 164, 365 to 384 (1967). Theory
- B. R. Judd, H. M. Crosswhite and H. Crosswhite, Phys. Rev. 169, 130 to
138 (1968). Theory

Ce IV

- A. S. King and R. B. King, Astroph. J. 75, 40 to 45 (1932). W L
- R. J. Lang, Can. J. Research [A] 13, 1 to 4 (1935); [A] 14, 127 to 130
(1936). I P, T, C L
- R. J. Lang, Phys. Rev. 49, 552 (L) (1936). I P, T, C L
- H. J. van de Vliet, Dissertation, Univ. Amsterdam, pp. 27 to 29
(N. V. Noord-Hollandsche Uitgevers Maatschappij, Amsterdam)(1939). Z E
- J. Sugar and V. Kaufman, unpublished observations (1969).
Vac. Ultraviolet

PRASEODYMIUM (Z = 59)

Pr I

- A. S. King, Astroph. J. 68, 219 to 245 (1928). Temperature Classification
- H. Lew, Phys. Rev. 89, 530 (L) (1953). hfs
- V. B. Belyanin, Opt. i Spektr. 4, 264 to 266 (1958). hfs
- K. Murakawa, J. Phys. Soc. Japan 15, 2306 to 2309 (1960). hfs
- A. Y. Cabezas, I. P. A. Lindgren, R. Marrus and W. A. Nierenberg, Phys.
Rev. 126, 1004 to 1008 (1962). hfs, Z E

PRASEODYMIUM

Pr I - Continued

- J. G. Conway and B. G. Wybourne, Phys. Rev. 130, 2325 to 2332 (1963).
Theory
- R. Zalubas and M. Wilson, J. Research Nat. Bur. Std. 69A, 59 to 70
(1965). W L
- J. Reader and J. Sugar, J. Opt. Soc. Am. 56, 1189 to 1194 (1966). I P
- R. Zalubas, unpublished material (1969). T, C L, Z E, W L

Pr II

- A. S. King, Astroph. J. 68, 219 to 245 (1928). Temperature Classification
- N. Rosen, G. R. Harrison and J. R. McNally, Jr., Phys. Rev. 60, 722 to
730 (1941). T, C L, Z E, hfs
- PH. Schuurmans, Dissertation, Univ. Amsterdam, pp. 36 to 39 (N. V. Noord-
Hollandsche Uitgevers Maatschappij, Amsterdam) (1946). T, Z E, hfs
- P. Brix, Phys. Rev. 89, 1245 to 1246 (1953). hfs
- G. Racah, unpublished material (1956). Configurations
- V. B. Belyanin, Opt. i Spektr. 4, 264 to 266 (1958). hfs, C L
- K. Murakawa, J. Phys. Soc. Japan 15, 2306 to 2309 (1960). hfs
- J. Sugar and J. Reader, J. Opt. Soc. Am. 55, 1286 to 1290 (1965). I P
- R. Zalubas, unpublished material (1968). W L, Z E

Pr III

- J. Sugar, Johns Hopkins Spectr. Report No. 22, 87 pp. (1961). I P, T,
C L, E D, W L
- J. Sugar, J. Opt. Soc. Am. 53, 831 to 839 (1963). I P, T, C L, E D
- N. Spector, J. Opt. Soc. Am. 54, 1359 to 1362 (1964). Energy Levels
Theory

PRASEODYMIUM

Pr III - Continued

- R. E. Trees, J. Opt. Soc. Am. 54, 651 to 657 (1964). Energy Levels Z E Theory
- K. Rajnak, J. Opt. Soc. Am. 55, 126 to 132 (1965). Theory $4f^3$ Configuration
- J. Reader and J. Sugar, Phys. Rev. 137, B784 to B789 (1965). hfs, C L
- H. Crosswhite, H. M. Crosswhite and B. R. Judd, Phys. Rev. 174, 89 to 94 (1968). Theory
- Z. B. Goldschmidt, A. Pasternak and Z. H. Goldschmidt, unpublished material (1968). Theory $4f^3$ Configuration
- B. R. Judd, J. Opt. Soc. Am. 58, 1311 to 1312 (L) (1968). E D, Theory
- J. Sugar, J. Research Nat. Bur. Std. 73A, in press (1969). I P, T, C L, W L, E D, Theory

Pr IV

- E. Trefftz, Zeit. Phys. 130, 561 to 564 (1951). Theory
- W. A. Runciman and B. G. Wybourne, J. Chem. Phys. 31, 1149 to 1150 (L) (1959). Theory
- C. J. Lenander, Phys. Rev. 130, 1033 to 1035 (1963). Theory
- E. Y. Wong, J. Chem. Phys. 38, 976 to 978 (1963). Theory
- H. M. Crosswhite, G. H. Dieke and W. J. Carter, J. Chem. Phys. 43, 2047 to 2054 (1965). T, C L, hfs
- J. Sugar, J. Opt. Soc. Am. 55, 1058 to 1061 (1965). T, C L, Theory
- J. Sugar, Phys. Rev. Lett. 14, 731 to 732 (1965). T
- Z. H. Goldschmidt, Program Atomic Sp. Symposium, Nat. Bur. Std., p. 32 (A) (September 1967). Theory $4f^2$ Configuration
- W. T. Carnall, P. R. Fields and K. Rajnak, J. Chem. Phys. 49, 4424 to 4442 (1968). T Free Ion Spectra, Theory
- B. R. Judd, H. M. Crosswhite and H. Crosswhite, Phys. Rev. 169, 130 to 138 (1968). Theory
- J. Sugar, Analysis being extended (1969).

PRASEODYMIUM

Pr v

V. Kaufman and J. Sugar, J. Research Nat. Bur. Std. 71A, 583 to 585 (1967). I P, T, C L, hfs

NEODYMIUM (Z = 60)

Nd I

A. S. King, Astroph. J. 78, 9 to 45 (1933). Temperature Classification

F. W. Paul, Phys. Rev. 49, 156 to 162 (1936). W L Absorption

H. J. van de Vliet, Dissertation, Univ. Amsterdam, pp. 70 to 80 (N. V. Noord-Hollandsche Uitgevers Maatschappij, Amsterdam) (1939). Z E

P. F. A. Klinkenberg, Physica 12, 33 to 48 (1946). T, W L, Z E

PH. Schuurmans, Dissertation, Univ. Amsterdam, pp. 39 to 48 (N. V. Noord-Hollandsche Uitgevers Maatschappij, Amsterdam) (1946). T, C L, Z E

PH. Schuurmans, Physica 11, 419 to 425 (1946). T

K. Murakawa, Phys. Rev. 96, 1543 to 1546 (1954). hfs, I S

G. Nöldeke und A. Steudel, Zeit. Phys. 137, 632 to 637 (1954). I S, hfs

P. F. A. Klinkenberg, Dissertation, Univ. Amsterdam (1955). T, C L, Z E

F. A. Korolev and Yu. I. Osipov, Doklady Akad. Nauk SSSR 110, 365 to 367 (1956). I S

J. Blaise, Ann. de Phys. [13] 3, 1062 to 1067 (1958). I S, C L

K. F. Smith and I. J. Spalding, Proc. Roy. Soc. London A265, 133 to 140 (1961). Z E Atomic Beam

G. E. M. A. Hassan, Dissertation, Univ. Amsterdam, 175 pp. (1962). I P?, T, C L, Z E, I S, W L

J. G. Conway and B. G. Wybourne, Phys. Rev. 130, 2325 to 2332 (1963). Theory

G. E. M. A. Hassan, Physica 29, 1119 to 1127 (1963). I P?, T, C L, Z E, E D

NEODYMIUM

Nd I - Continued

- G. E. M. A. Hassan and P. F. A. Klinkenberg, *Physica* 29, 1133 to 1154 (1963). C L, Z E, I S
- I. J. Spalding, *Proc. Phys. Soc. (London)* 81, 156 to 162 (1963). hfs
- S. Held, Israel Atomic Energy Commission Report 1A-927, 37 pp. (June 1964). W L
- S. Gerstenkorn, J.-M. Helbert et R. Chabbal, *Compt. Rend.* 261, 1232 to 1235 (1965). I S
- G. Gluck, *Ann. de Phys. [13]* 10, 673 to 696 (1965). I S
- S. Gerstenkorn, unpublished material (1966). Near Infrared Observations 0.8μ to 2.5μ
- J. Reader and J. Sugar, *J. Opt. Soc. Am.* 56, 1189 to 1194 (1966). I P
- J. E. Hansen, A. Steudel und H. Walther, *Zeit. Phys.* 203, 296 to 329 (1967). I S
- J.-F. Wyart, Thèse, Univ. Paris (Orsay), 105 pp. (1968). T, C L, Z E, W L, E D, I S, Theory

Nd II

- A. S. King, *Astroph. J.* 78, 9 to 45 (1933). Temperature Classification
- H. J. van de Vliet, Dissertation, Univ. Amsterdam, pp. 70 to 80 (N. V. Noord-Hollandsche Uitgevers Maatschappij, Amsterdam) (1939). Z E
- W. E. Albertson, G. R. Harrison and J. R. McNally, Jr., *Phys. Rev.* 61, 167 to 174 (1942). T, C L, Z E
- P. F. A. Klinkenberg, *Physica* 12, 33 to 48 (1946). W L, Z E
- PH. Schuurmans, *Physica* 11, 419 to 425 (1946). T, C L, Z E
- K. Murakawa, *Phys. Rev.* 96, 1543 to 1546 (1954). hfs
- G. Nöldeke, *Zeit. Phys.* 143, 274 to 284 (1955). I S, hfs
- J. Blaise, *Ann. de Phys. [13]* 3, 1062 to 1067 (1958). I S, C L

NEODYMIUM

Nd II - Continued

- G. E. M. A. Hassan, Dissertation, Univ. Amsterdam, 175 pp. (1962). T, C L, E D, I S, W L
- S. Held, Israel Atomic Energy Commission Report 1A-927, 37 pp. (June 1964). W L
- J. Sugar and J. Reader, J. Opt. Soc. Am. 55, 1286 to 1290 (1965). I P
- S. Gerstenkorn, unpublished material (1966). Near Infrared Observations
- J.-F. Wyart, Thèse, Univ. Paris (Orsay), 105 pp. (1968). T, C L, W L, Z E, Theory

Nd III

- H. M. Crosswhite, Private communication (1965). Unpublished W L

Nd IV

- B. G. Wybourne, J. Chem. Phys. 32, 639 to 642 (1960); 34, 279 to 281 (1961). Theory
- H. Crosswhite, H. M. Crosswhite and B. R. Judd, Phys. Rev. 174, 89 to 94 (1968). Theory
- A. Rajnak, J. Chem. Phys. 43, 847 to 855 (1965). Theory
- W. T. Carnall, P. R. Fields and K. Rajnak, J. Chem. Phys. 49, 4424 to 4442 (1968). T Free Ion Spectra, Theory
- M. Synek and L. Corsiglia, J. Chem. Phys. 48, 3121 to 3125 (1968). Theory

PROMETHIUM (Z = 61)

Pm I

- W. F. Meggers, B. F. Scribner and W. R. Bozman, J. Research Nat. Bur. Std. 46, 85 to 98, RP2179 (1951). W L
- P. F. A. Klinkenberg and F. S. Tomkins, Physica 26, 103 to 114 (1960). hfs

PROMETHIUM

Pm I - Continued

- A. Y. Cabezas, I. Lindgren and R. Marrus, Phys. Rev. 122, 1796 to 1801 (1961). Z E Atomic Beam
- B. Budick and R. Marrus, Phys. Rev. 132, 723 to 728 (1963). hfs, Z E
- J. G. Conway and B. G. Wybourne, Phys. Rev. 130, 2325 to 2332 (1963). Theory
- J. Reader and J. Sugar, J. Opt. Soc. Am. 56, 1189 to 1194 (1966). I P
- J. Reader and S. P. Davis, J. Research Nat. Bur. Std. 71A, 587 to 599 (1967). T, C L, Z E
- B. R. Judd, H. M. Crosswhite and H. Crosswhite, Phys. Rev. 169, 130 to 138 (1968). Theory

Pm II

- W. F. Meggers, B. F. Scribner and W. R. Bozman, J. Research Nat. Bur. Std. 46, 85 to 98, RP2179 (1951). W L
- P. F. A. Klinkenberg and F. S. Tomkins, Physica 26, 103 to 114 (1960). hfs
- J. Reader and S. P. Davis, J. Opt. Soc. Am. 53, 431 to 435 (1963). hfs
- J. Sugar and J. Reader, J. Opt. Soc. Am. 55, 1286 to 1290 (1965). I P
- J. Reader, Phys. Rev. 141, 1123 to 1128 (1966). hfs
- J. Reader and S. P. Davis, Program Atomic Sp. Symposium, Nat. Bur. Std., p. 79 (A) (1967). T
- J. Reader and S. P. Davis, unpublished analysis (1969).

Pm IV

- M. H. Crozier and W. A. Runciman, J. Chem. Phys. 35, 1392 to 1409 (1961). Theory, Z E
- S. Hufner, Zeit. Phys. 165, 397 to 401 (1961). Theory
- W. T. Carnall, P. R. Fields and K. Rajnak, J. Chem. Phys. 49, 4412 to 4442 (1968). T Free Ion Spectra, Theory

SAMARIUM (Z = 62)

Sm I

- W. Albertson, Phys. Rev. 47, 370 to 376 (1935); 52, 644 to 647 (1937).
I P, T, C L
- A. S. King, Astroph. J. 82, 140 to 191 (1935). Temperature Classification
- F. W. Paul, Phys. Rev. 49, 156 to 162 (1936). W L Absorption
- P. Brix, Zeit. Phys. 126, 431 to 439 (1949). T, C L, I S
- K. Murakawa, Phys. Rev. 93, 1232 to 1235 (1954). hfs
- F. M. J. Pichanick and G. K. Woodgate, Proc. Roy. Soc. London A263, 89 to 100 (1961). Z E, Ground Term
- K. F. Smith and I. J. Spalding, Proc. Roy. Soc. London A265, 133 to 140 (1961). Z E Atomic Beam
- A. R. Striganov, V. A. Katulin and V. V. Eliseev, Opt. i Spektr. 12, 171 to 177 (1962). I S, C L
- J. G. Conway and B. G. Wybourne, Phys. Rev. 130, 2325 to 2332 (1963).
Theory
- S. Held, Israel Atomic Energy Commission Report 1A-841, 46 to 47 (1963).
W L
- W. H. King, J. Opt. Soc. Am. 53, 638 to 639 (L) (1963). I S
- S. Gerstenkorn, unpublished material (1966). Near Infrared Observations
0.8 μ to 2.5 μ
- K. Heileg, G. Sauthoff und A. Steudel, Zeit. Phys. 196, 39 to 43 (1966).
Z E
- G. Racah and U. Ganiel, J. Opt. Soc. Am. 56, 893 to 895 (1966). Theory
- J. Reader and J. Sugar, J. Opt. Soc. Am. 56, 1189 to 1194 (1966). I P
- A. Carlier, Thèse (Orsay) (1967). Theory, T, C L
- J. E. Hansen, A. Steudel und H. Walther, Zeit. Phys. 203, 296 to 329 (1967). I S
- A. Carlier, J. Blaise et M.-G. Schweighofer, J. de Phys. 29, 729 to 738 (1968). T, E D, Z E, Theory
- J. Blaise, C. Morillon, M.-G. Schweighofer et J.-L. Verges, Spectrochim. Acta, in press (1969). Emission Spectra T, C L

SAMARIUM

Sm II

- A. S. King, *Astroph. J.* 82, 140 to 191 (1935). Temperature Classification
- W. Albertson, *Astroph. J.* 84, 26 to 72 (1936). I P, T, C L, Z E
- K. Murakawa, *Phys. Rev.* 93, 1232 to 1235 (1954). hfs
- S. Held, Israel Atomic Energy Commission Report LA-841, 46 to 47 (1963).
W L
- A. R. Striganov and N. A. Kulazhenkova, *Opt. i Spektr.* 16, 936 to 940
(1964). I S, C L
- H. M. Crosswhite, unpublished material (1965). W L
- J. Sugar and J. Reader, *J. Opt. Soc. Am.* 55, 1286 to 1290 (1965). I P
- A. Carlier, Thèse (Orsay) (1967). Theory
- J. Blaise, C. Morillon, M.-G. Schweighofer et J.-L. Vergès, *Opt. Conf. Warsaw* (June 1968); *Spectrochim. Acta*, in press (1968). T, C L, I S,
Z E, Observations 0.8μ to 2.5μ

Sm III

- G. S. Ofelt, *J. Chem. Phys.* 38, 2171 to 2180 (1963). Theory
 $4f^6$ Configuration, T, Z E
- H. M. Crosswhite, unpublished material (1965). W L
- A. Dupont, *J. Opt. Soc. Am.* 57, 867 to 869 (1967). T, E D

Sm IV

- B. R. Judd, *Proc. Phys. Soc. (London)* A69, 157 to 164 (1956). Theory
Ground Term
- B. G. Wybourne, *J. Chem. Phys.* 36, 2301 to 2311 (1962). Theory, f^n Terms
- W. T. Carnall, P. R. Fields and K. Rajnak, *J. Chem. Phys.* 49, 4412 to
4442 (1968). T Free Ion Spectra, Theory

EUROPIUM (Z = 63)

Eu I

- A. S. King, *Astroph. J.* 72, 221 to 255 (1930). Temperature Classification,
hfs
- H. N. Russell and A. S. King, *Phys. Rev.* 46, 1023 to 1024 (1934). I P,
T, C L
- A. S. King, *Astroph. J.* 89, 377 to 430 (1939). Temperature Classification
- H. N. Russell and A. S. King, *Astroph. J.* 90, 155 to 203 (1939). I P,
T, C L
- H. N. Russell, W. Albertson and D. N. Davis, *Phys. Rev.* 60, 653 (1941).
C L, Z E
- P. Brix, *Zeit. Phys.* 132, 579 to 607 (1952). I S
- F. M. Pichanick, P. G. H. Sandars and G. K. Woodgate, *Proc. Roy. Soc. London* A257, 277 to 282 (1960). hfs
- P. G. H. Sandars and G. K. Woodgate, *Proc. Roy. Soc. London* A257, 269 to 276 (1960). hfs, Z E
- K. Krebs und R. Winkler, *Ann. der Phys.* [7] 7, 77 to 83 (1961). hfs
- F. M. J. Pichanick and G. K. Woodgate, *Proc. Roy. Soc. London* A263, 89 to 100 (1961). Z E, Ground Term
- J. G. Conway and B. G. Wybourne, *Phys. Rev.* 130, 2325 to 2332 (1963).
Theory
- S. Held, Israel Atomic Energy Commission Report 1A-841, 40 to 45 (1963).
W L
- Y. Bordarier, B. R. Judd and M. Klapisch, *Proc. Roy. Soc. London* A289,
81 to 96 (1965). hfs Theory
- W. Müller, A. Steudel und H. Walther, *Zeit. Phys.* 183, 303 to 320 (1965).
hfs
- G. Smith and B. G. Wybourne, *J. Opt. Soc. Am.* 55, 121 to 125 (1965). T,
Z E Theory
- R. Winkler, *Zeit. Phys.* 184, 433 to 450 (1965). hfs
- J. Reader and J. Sugar, *J. Opt. Soc. Am.* 56, 1189 to 1194 (1966). I P
- P. Bagus et J. Picart, *Compt. Rend.* 266B, 842 to 844 (1968). hfs

EUROPIUM

Eu II

- A. S. King, *Astroph. J.* 72, 221 to 255 (1930). Temperature Classification, hfs
- W. Albertson, *Phys. Rev.* 45, 499 to 500 (L) (1934). T, C L
- A. S. King, *Astroph. J.* 89, 377 to 430 (1939). Temperature Classification
- H. N. Russell, W. Albertson and D. N. Davis, *Phys. Rev.* 60, 641 to 656 (1941). I P, T, C L, Z E
- P. Brix, *Zeit. Phys.* 132, 579 to 607 (1952). I S
- K. Krebs und R. Winkler, *Zeit. Phys.* 160, 320 to 332 (1960). hfs, I S
- S. Held, Israel Atomic Energy Commission Report 1A-841, 40 to 45 (1963). W L
- B. G. Wybourne, *J. Opt. Soc. Am.* 54, 267 (L) (1964). Z E
- J. Sugar and J. Reader, *J. Opt. Soc. Am.* 55, 1286 to 1290 (1965). I P
- R. Winkler, *Zeit. Phys.* 184, 433 to 450 (1965). hfs
- I. Koniordos und R. Winkler, *Phys. Lett. (Amsterdam)* A27, 198 to 199 (1968). I S

Eu III

- A. S. King, *Astroph. J.* 89, 377 to 430 (1939). Temperature Classification
- H. N. Russell, W. Albertson and D. N. Davis, *Phys. Rev.* 60, 653 (1941). W L, Z E
- P. Bagus et J. Picart, *Compt. Rend.* 266B, 842 to 844 (1968). hfs
- I. Koniordos und R. Winkler, *Phys. Lett. (Amsterdam)* A27, 198 to 199 (1968). I S

EUROPIUM

Eu IV

- B. R. Judd, Proc. Phys. Soc. (London) A69, 157 to 164 (1956). Theory Ground Term
- J. B. Gruber and J. G. Conway, J. Chem. Phys. 34, 632 to 638 (1961). T, f^6 Configuration Theory
- G. S. Ofelt, J. Chem. Phys. 38, 2171 to 2180 (1963). Theory $4f^6$ Configuration T, Z E
- W. T. Carnall, P. R. Fields and K. Rajnak, J. Chem. Phys. 49, 4412 to 4423, 4450 to 4455 (1968). T Free Ion Spectra, Theory

GADOLINIUM (Z = 64)

Gd I

- A. S. King, Astroph. J. 72, 221 to 255 (1930). Temperature Classification
- W. Albertson, Phys. Rev. 47, 370 to 376 (1935); 49, 208 (A) (1936). T, C L
- H. N. Russell, Astroph. J. 96, 11 to 14 (1942). I P, T, C L
- A. S. King, Astroph. J. 97, 323 to 380 (1943). W L, Temperature Classification
- P. F. A. Klinkenberg, Physica 12, 33 to 48 (1946). T, C L, Z E, I S
- H. N. Russell, J. Opt. Soc. Am. 40, 550 to 575 (1950). I P, T, C L
- P. Brix, Zeit. Phys. 132, 579 to 607 (1952). I S
- P. Brix and H. D. Engler, Zeit. Phys. 133, 362 to 369 (1952). I S, T, C L
- S. Suwa, Phys. Rev. 86, 247 to 248 (L) (1952). hfs
- K. Murakawa, Phys. Rev. 96, 1543 to 1546 (1954). hfs, I S
- D. R. Speck, Phys. Rev. 101, 1725 to 1729 (1956). I S, hfs
- H. Kopfermann, L. Krüger und A. Steudel, Ann. der Phys. [6] 20, 258 to 264 (1957). I S
- K. F. Smith and I. J. Spalding, Proc. Roy. Soc. London A265, 133 to 140 (1961). Z E Atomic Beam
- E. H. Pinnington, J. Opt. Soc. Am. 57, 1252 to 1259 (1967). T, C L, Z E
- N. Spector, Analysis in progress (1968).

GADOLINIUM

Gd II

- A. S. King, *Astroph. J.* 72, 221 to 255 (1930). Temperature Classification
- W. E. Albertson, H. Bruynes and R. Hanau, *Phys. Rev.* 57, 292 to 293 (1940). T, C L, Z E
- H. N. Russell, *Astroph. J.* 96, 11 to 14 (1942). T
- A. S. King, *Astroph. J.* 97, 323 to 380 (1943). W L, Temperature Classification
- H. N. Russell, *J. Opt. Soc. Am.* 40, 550 to 575 (1950). I P, T, C L
- P. Brix, *Zeit. Phys.* 132, 579 to 607 (1952). I S
- N. Zeldes, *Phys. Rev.* 90, 413 to 415 (1953). Theory
- P. Brix und K.-H. Lindenberger, *Zeit. Phys.* 141, 1 to 5 (1955). I S, T, C L
- H. Kopfermann, L. Krüger und A. Steudel, *Ann. der Phys.* [6] 20, 258 to 264 (1957). I S
- G. Racah, unpublished material (1963). T, C L
- Z. B. Goldschmidt and S. Nir, Revised analysis (1965). T, Theory
- G. Smith and B. G. Wybourne, *J. Opt. Soc. Am.* 55, 1278 to 1283 (1965). Theory T, Z E
- J. Sugar and J. Reader, *J. Opt. Soc. Am.* 55, 1286 to 1290 (1965). I P
- D. Desmarais and E. H. Pinnington, *J. Opt. Soc. Am.* 57, 1245 to 1251 (1967). T, C L, Z E
- N. Spector, Analysis in progress (1968); *J. Opt. Soc. Am.* 59, in press (A) (February 1969). T

Gd III

- A. S. King, *Astroph. J.* 97, 323 to 380 (1943). W L
- W. R. Callahan, *J. Opt. Soc. Am.* 53, 695 to 700 (1963). T, C L
- H. Crosswhite, Analysis in progress, Johns Hopkins Univ. (1968).

GADOLINIUM

Gd IV

B. R. Judd, H. M. Crosswhite and H. Crosswhite, Phys. Rev. 169, 130 to 138 (1968). Theory

W. T. Carnall, P. R. Fields and K. Rajnak, J. Chem. Phys. 49, 4412 to 4423, 4443 to 4446 (1968). T Free Ion Spectra, Theory

TERBIUM (Z = 65)

Tb I

A. S. King, Astroph. J. 72, 221 to 255 (1930). Temperature Classification, hfs

S. P. Davis, Astroph. J. 132, 486 to 492 (1960). W L, hfs, Z E

J. Sugar, J. Research Nat. Bur. Std. 66A, 321 to 324 (1962). Ground State

J. G. Conway and B. G. Wybourne, Phys. Rev. 130, 2325 to 2332 (1963). Theory

I. Bender, S. Penselin und K. Schlüpmann, Zeit. Phys. 179, 4 to 8 (1964). Ground State, Z E, hfs

P. F. A. Klinkenberg, Zeit. Phys. 180, 174 to 177 (1964). Ground State, Z E

C. Arnoult and S. Gerstenkorn, J. Opt. Soc. Am. 56, 177 to 181 (1966). T, Z E, hfs, Theory

S. Gerstenkorn, unpublished material (1966). Near Infrared Observations 0.8 μ to 2.5 μ

P. F. A. Klinkenberg, Physica 32, 1113 to 1147 (1966). T, C L, Z E

P. F. A. Klinkenberg and E. Meinders, Physica 32, 1617 to 1632 (1966). T, C L, Z E, hfs

P. F. A. Klinkenberg, Physica 37, 197 to 214 (1967). T, C L, Z E

E. Meinders and P. F. A. Klinkenberg, Physica 38, 253 to 274 (1968). T, C L, Z E, W L

W. J. Childs and L. S. Goodman, Bull. Am. Phys. Soc. 14, 84 (1969). Z E Atomic Beam

TERBIUM

Tb II

- A. S. King, *Astroph. J.* 72, 221 to 255 (1930). Temperature Classification, hfs
- S. P. Davis, *Astroph. J.* 132, 486 to 492 (1960). W L, hfs, Z E
- J. Sugar and J. Reader, *J. Opt. Soc. Am.* 55, 1286 to 1290 (1965). I P

Tb IV

- B. R. Judd, *Proc. Phys. Soc. (London)* A69, 157 to 164 (1956). Theory Ground Term
- G. S. Ofelt, *J. Chem. Phys.* 38, 2171 to 2180 (1963). Theory $4f^8$ Configuration, T, Z E
- W. T. Carnall, P. R. Fields and K. Rajnak, *J. Chem. Phys.* 49, 4412 to 4423, 4447 to 4449 (1968). T Free Ion Spectra, Theory

DYSPROSIUM (Z = 66)

Dy I

- A. S. King, *Astroph. J.* 72, 221 to 255 (1930). Temperature Classification
- A. S. King, unpublished material (1953). Temperature Classification
- K. Murakawa and T. Kamei, *Phys. Rev.* 92, 325 to 327 (1953). hfs
- Yu. P. Dontsov, *Opt. i Spektr.* 1, 612 to 616 (1956). I S
- K. Murakawa, *J. Phys. Soc. Japan* 11, 804 to 805 (1956). hfs
- A. I. Akimov, *Opt. i Spektr.* 3, 545 to 551 (1957). W L
- A. Y. Cabezas, I. Lindgren and R. Marrus, *Phys. Rev.* 122, 1796 to 1801 (1961). Z E Atomic Beam
- K. F. Smith and I. J. Spalding, *Proc. Roy. Soc. London* A265, 133 to 140 (1961). Z E Atomic Beam
- J. G. Conway and B. G. Wybourne, *Phys. Rev.* 130, 2325 to 2332 (1963). Theory

DYSPROSIUM

Dy I - Continued

- W. F. Meggers, unpublished material (1963). T, C L
- A. R. Striganov, A. F. Golovin a M. P. Gerasimova, Opt. i Spektr. 14, 7 to 11 (1963). I S
- J. Reader and J. Sugar, J. Opt. Soc. Am. 56, 1189 to 1194 (1966). I P
- W. Ebenhöh, V. J. Ehlers und J. Ferch, Zeit. Phys. 200, 84 to 92 (1967). hfs, Z E
- A. F. Golovin a I. F. Kramer, Opt. i Spektr. 23, 195 to 199 (1967). I S
- J. G. Conway and E. F. Worden, J. Opt. Soc. Am. 58, 1564 (A) (1968). T, Analysis in progress

Dy II

- A. S. King, Astroph. J. 72, 221 to 255 (1930). Temperature Classification
- A. S. King and C. E. Moore, Astroph. J. 98, 33 to 42 (1943). W L, Solar Identifications
- J. M. Blank, Thesis, Mass. Inst. Tech., Cambridge, Mass. (1953). T, C L
- A. S. King, unpublished material (1953). Temperature Classification
- K. Murakawa and T. Kamei, Phys. Rev. 92, 325 to 327 (1953). hfs
- G. Racah, unpublished material (1955). T, C L
- Yu. P. Dontsov, Opt. i Spektr. 1, 612 to 616 (1956). I S
- K. Murakawa, J. Phys. Soc. Japan 11, 804 to 805 (1956). hfs
- A. I. Akimov, Opt. i Spektr. 3, 545 to 551 (1957). W L
- J. R. McNally, Jr., Letter (1959). T, Z E
- W. F. Meggers and C. H. Corliss, unpublished material (1961). T, C L
- J. Sugar and J. Reader, J. Opt. Soc. Am. 55, 1286 to 1290 (1965). I P
- J. G. Conway and E. F. Worden, J. Opt. Soc. Am. 58, 1564 (A) (1968). T, Analysis in progress

DYSPROSIUM

Dy IV

- B. R. Judd, Proc. Phys. Soc. (London) A69, 157 to 164 (1956). Theory Ground Term
- B. G. Wybourne, J. Chem. Phys. 36, 2301 to 2311 (1962). Theory, f^n Terms
- W. T. Carnall, P. R. Fields and K. Rajnak, J. Chem. Phys. 49, 4412 to 4442 (1968). T Free Ion Spectra, Theory

HOLMIUM (Z = 67)

Ho I

- A. S. King, Astroph. J. 72, 221 to 255 (1930). Temperature Classification, hfs
- V. B. Belyanin, Opt. i Spektr. 3, 322 to 327; 5, 236 to 238, 340 to 341 (1958). hfs, W L
- A. Y. Cabezas, I. Lindgren and R. Marrus, Phys. Rev. 122, 1796 to 1801 (1961). Z E Atomic Beam
- J. G. Conway and B. G. Wybourne, Phys. Rev. 130, 2325 to 2332 (1963). Theory
- L. S. Goodman und K. Schlüpmann, Zeit. Phys. 178, 235 to 243 (1964). hfs, Z E
- S. Gerstenkorn, unpublished material (1966). Near Infrared Observations 0.8μ to 2.5μ
- J. Reader and J. Sugar, J. Opt. Soc. Am. 56, 1189 to 1194 (1966). I P
- N. Spector and J. Sugar, Analysis in progress (1969).

Ho II

- A. S. King, Astroph. J. 72, 221 to 255 (1930). Temperature Classification, hfs
- A. Przybylski, Acta Astronomica 13, 217 to 229 (1963). Stellar Identifications
- J. Sugar and J. Reader, J. Opt. Soc. Am. 55, 1286 to 1290 (1965). I P

HOLMIUM

Ho II - Continued

- J. Sugar, J. Opt. Soc. Am. 58, 1519 to 1523 (1968). hfs, Levels, E D
N. Spector and J. Sugar, Analysis in progress (1969).
B. Belyanin, Opt. i Spektr. 3, 322 to 327 (1957). hfs, W L

Ho III

- J. H. McElaney, J. Opt. Soc. Am. 57, 870 to 872 (1967). T, E D
H. M. Crosswhite, Analysis being extended (1968).

Ho IV

- B. R. Judd, Proc. Phys. Soc. (London) A69, 157 to 164 (1956). Theory
Ground Term
M. H. Crozier and W. A. Runciman, J. Chem. Phys. 35, 1392 to 1409 (1961).
Theory, Z E
S. Hufner, Zeit. Phys. 164, 257 to 268, 269 to 273 (1961); 166, 242
(1962). Theory f^4 Configuration
W. T. Carnall, P. R. Fields and K. Rajnak, J. Chem. Phys. 49, 4412 to
4442 (1968). T Free Ion Spectra, Theory

ERBIUM (Z = 68)

Er I

- K. Murakawa and S. Suwa, Phys. Rev. 85, 683 to 684 (L) (1952). hfs, I S
A. G. Shenstone, unpublished material (1952). W L Vac. Ultraviolet
A. I. Akimov, Opt. i Spektr. 3, 545 to 551 (1957). W L
J. W. Lindner and S. P. Davis, J. Opt. Soc. Am. 48, 542 to 547 (1958).
Z E, W L
A. Y. Cabezas, I. Lindgren and R. Marrus, Phys. Rev. 122, 1796 to 1801
(1961). Z E Atomic Beam

ERBIUM

Er I - Continued

- K. F. Smith and I. J. Spalding, Proc. Roy. Soc. London A265, 133 to 140 (1961). Z E Atomic Beam
- J. G. Conway, unpublished material (1962). W L
- J. G. Conway and B. G. Wybourne, Phys. Rev. 130, 2325 to 2332 (1963). Theory
- W. M. Doyle and R. Marrus, Phys. Rev. 131, 1586 to 1588 (1963). hfs, Z E
- S. Held, Israel Atomic Energy Commission Report 1A-813, 23 pp. (1963). W L
- M. Wilson, Observations (1963). Absorption Spectra
- D. A. Volkov a A. F. Golovin, Opt. i Spektr. 18, 185 to 189 (1965). I S
- E. Paul Haynes, II and John S. Ross, Phys. Rev. 137, B790 to B792 (1965). I S
- L. C. Marquet and W. E. Behring, J. Opt. Soc. Am. 55, 576 (L) (1965). T
- L. C. Marquet and S. P. Davis, J. Opt. Soc. Am. 55, 471 to 474 (1965). T, Z E
- K. F. Smith and P. J. Unsworth, Proc. Phys. Soc. (London) 86, 1249 to 1257 (1965). hfs
- N. Spector, J. Opt. Soc. Am. 55, 576 to 577 (L) (1965). T
- G. Racah, Z. B. Goldschmidt and S. Toaff, J. Opt. Soc. Am. 56, 407 to 408 (L) (1966). T, Z E, E D, Theory
- J. Reader and J. Sugar, J. Opt. Soc. Am. 56, 1189 to 1194 (1966). I P
- N. Spector, J. Opt. Soc. Am. 56, 341 to 349 (1966). T, C L Absorption, Z E, E D, Theory
- A. F. Golovin a I. F. Kramer, Opt. i Spektr. 23, 195 to 199 (1967). I S
- K. Heilig and A. Steudel, Program Atomic Sp. Symposium, Nat. Bur. Std., p. 16 (1967). Z E
- N. Spector, J. Opt. Soc. Am. 57, 308 to 311 (1967). T, E D, C L
- K. Heilig und O. Kircher, Zeit. Phys. 212, 243 to 247 (1968). Z E, W L, C L

ERBIUM

Er II

- L. Wilets and L. C. Bradley, III, Phys. Rev. 84, 1055 to 1056 (L) (1951).
I S
- A. G. Shenstone, unpublished material (1952). W L Vac. Ultraviolet
- L. Wilets and L. C. Bradley, III, Phys. Rev. 87, 1018 to 1022 (1952). I S
- A. I. Akimov, Opt. i Spektr. 3, 545 to 551 (1957). W L
- J. W. Lindner and S. P. Davis, J. Opt. Soc. Am. 48, 542 to 547 (1958).
Z E, W L
- J. R. McNally, Jr. and K. L. Vander Sluis, J. Opt. Soc. Am. 49, 200 (L)
(1959). T, Z E
- K. L. Vander Sluis, unpublished material (1960). T, C L
- B. R. Judd and L. C. Marquet, J. Opt. Soc. Am. 52, 504 to 507 (1962).
T, Z E, E D, Theory
- Z. B. Goldschmidt, J. Opt. Soc. Am. 53, 594 to 595 (1963). T, Z E,
Theory
- S. Held, Israel Atomic Energy Commission Report 1A-813, 23 pp. (1963).
W L
- L. C. Marquet and W. E. Behring, J. Opt. Soc. Am. 54, 1403 (A) (1964).
Analysis being continued
- N. Spector, Observations (1964). W L, Z E
- J. Sugar and J. Reader, J. Opt. Soc. Am. 55, 1286 to 1290 (1965). I P
- F. P. J. Valero and S. P. Davis, J. Opt. Soc. Am. 55, 1572 (A) (1965).
hfs
- K. Heilig und O. Kircher, Zeit. Phys. 212, 243 to 247 (1968). Z E, W L

Er III

- H. M. Crosswhite, unpublished material (1965). W L
- J. Becker, Dissertation, The Johns Hopkins Univ. (1966). T, C L, Theory

ERBIUM

Er IV

- B. G. Wybourne, J. Chem. Phys. 32, 639 to 642 (1960); 34, 279 to 281 (1961). Theory
- K. Rajnak, J. Chem. Phys. 43, 847 to 855 (1965). Theory
- W. J. Carter, Dissertation, The Johns Hopkins Univ.; Dissertation Abstr. B27, 3642 (1967), Univ. Microfilms (Ann Arbor, Mich.) Order No. 66-12510, 107 pp. (1967). See Chem. Abstr. 66, 70635x (1967). T, C L W L
- W. J. Carter and H. M. Crosswhite, unpublished material (1969). T, C L, E D
- H. Crosswhite, H. M. Crosswhite and B. R. Judd, Phys. Rev. 174, 89 to 94 (1968). Theory
- Z. B. Goldschmidt, A. Pasternak and Z. H. Goldschmidt, unpublished material (1968). Theory $4f^{11}$ Configuration
- W. T. Carnall, P. R. Fields and K. Rajnak, J. Chem. Phys. 49, 4424 to 4442 (1968). T Free Ion Spectra, Theory

THULIUM (Z = 69)

Tm I

- W. Albertson, Phys. Rev. 47, 370 to 376 (1935). Configurations
- A. S. King, Astroph. J. 94, 226 to 231 (1941). Temperature Classification
- W. F. Meggers, Rev. Mod. Phys. 14, 96 to 103 (1942). T, C L
- L. F. H. Bovey and W. R. S. Garton, Proc. Phys. Soc. (London) A67, 476 to 477 (1954). W L Absorption
- G. Racah, unpublished material (1955).
- A. I. Akimov, Opt. i Spekt. 3, 545 to 551 (1957). W L
- A. Y. Cabezas and I. Lindgren, Phys. Rev. 120, 920 to 925 (1960). hfs, Z E
- L. Allen, United Kingdom, Atomic Energy Research Establishment AERE-R4029, 34 pp. (1962). Z E, W L

THULIUM

Tm I - Continued

- W. F. Meggers and J. Sugar, New description in progress (1962).
- G. J. Ritter, Phys. Rev. 128, 2238 to 2243 (1962). hfs, Z E
- J. Sugar, J. Research Nat. Bur. Std. 66A, 321 to 324 (1962). Ground States
- J. C. Walker, Phys. Rev. 127, 1739 to 1745 (1962). hfs, Z E
- J. Blaise et R. Vetter, Compt. Rend. 256, 630 to 633 (1963). I P, T, hfs
- Y. Bordarier, R. Vetter et J. Blaise, J. de Phys. 24, 1107 to 1112 (1963). hfs, C L, E D, Theory
- D. L. Kaminsky, K. M. Novik, N. I. Alekseyev and L. L. Varshalovich, Opt. i Spektr. 15, 441 to 445 (1963). hfs
- W. F. Meggers, Analysis in progress (1963). T, C L, Z E, W L
- J. Blaise et P. Camus, Compt. Rend. 260, 4693 to 4696 (1965). T, Z E
- P. Camus et J. Blaise, Compt. Rend. 261, 4359 to 4361 (1965). I P, T
- K. Murakawa, J. Phys. Soc. Japan 20, 1733 (1965). I P
- P. Camus, J. de Phys. 27, 717 to 725 (1966). Theory Z E E D
- S. Gerstenkorn, unpublished material (1966). Near Infrared Observations 0.8 μ to 2.5 μ
- J. Reader and J. Sugar, J. Opt. Soc. Am. 56, 1189 to 1194 (1966). I P
- P. Camus, J. L. Vergès, J. Sugar and W. F. Meggers, Program Atomic Sp. Symposium, Nat. Bur. Std., p. 29 (A) (September 1967). I P, Known configurations
- D. Giglberger and S. Penselin, Zeit. Phys. 199, 244 to 255 (1967). hfs, Z E
- J. Sugar, Analysis in progress (1969).
- B. Budick and A. Simievic, "Spectroscopic and Group Theoretical Methods in Physics", F. Bloch etc., Editors, pp. 161 to 165 (John Wiley and Sons, N. Y., 1968); Bull. Am. Phys. Soc. [2] 13, 171 (1968). hfs, Z E Atomic Beam

THULIUM

Tm II

- A. S. King, *Astroph. J.* 94, 226 to 231 (1941). Temperature Classification
- W. F. Meggers, *Rev. Mod. Phys.* 14, 96 to 103 (1942). T, C L
- K. H. Lindenberger, *Zeit. Phys.* 141, 476 to 485 (1955). hfs, T, C L
- A. I. Akimov, *Opt. i Spektr.* 3, 545 to 551 (1957). W L
- L. Allen, United Kingdom, Atomic Energy Research Establishment AERE-R4029, 34 pp. (1962). Z E, W L, T
- W. F. Meggers and J. Sugar, New description in progress (1962).
- J. Sugar, *J. Research Nat. Bur. Std.* 66A, 321 to 324 (1962). Ground States
- W. F. Meggers, Analysis in progress (1963). T, C L, Z E, W L
- J. Blaise et P. Camus, *Compt. Rend.* 260, 4693 to 4696 (1965). T, Z E
- P. Camus et J. Blaise, *Compt. Rend.* 261, 4359 to 4361 (1965). T
- J. Sugar and J. Reader, *J. Opt. Soc. Am.* 55, 1286 to 1290 (1965). I P
- N. Spector, *J. Opt. Soc. Am.* 57, 312 to 317 (1967). T, C L, E D, Theory
- J. Sugar, Analysis in progress (1969).

Tm III

- H. M. Crosswhite, unpublished material (1965). W L

Tm IV

- W. A. Runciman and B. G. Wybourne, *J. Chem. Phys.* 31, 1149 to 1150 (L) (1959). Theory
- J. B. Gruber and J. G. Conway, *J. Chem. Phys.* 32, 1178 to 1182 (1960). Theory
- W. T. Carnall, P. R. Fields and K. Rajnak, *J. Chem. Phys.* 49, 4424 to 4442 (1968). T Free Ion Spectra, Theory

YTTERBIUM (Z = 70)

Yb I

- A. S. King, *Astroph. J.* 74, 328 to 335 (1931). Temperature Classification
- W. F. Meggers and B. F. Scribner, *J. Research Nat. Bur. Std.* 19, 651 to 664, RP1053 (1938). T, C L, W L
- P. Brix, *Zeit. Phys.* 132, 579 to 607 (1952). I S
- K. Krebs and H. Nelkowski, *Zeit. Phys.* 145, 543 to 559 (1956). I S, hfs
- C. J. Humphreys and E. Paul, Jr., NAVORD Report 5970, 57 to 67 (1959).
W L Near Infrared
- W. F. Meggers and C. H. Corliss, *J. Opt. Soc. Am.* 50, 1136 (A) (1960).
T, Z E
- L. Allen, United Kingdom, Atomic Energy Research Establishment AERE-R4029, 34 pp. (1962). Z E, W L
- J. S. Ross and K. Murakawa, *Phys. Rev.* 128, 1159 to 1160 (1962). hfs
- J. Sugar, *J. Research Nat. Bur. Std.* 66A, 321 to 324 (1962). T
- W. F. Meggers, unpublished analysis (February 1963).
- J. S. Ross, *J. Opt. Soc. Am.* 53, 299 to 300 (L) (1963). I S, hfs
- J. S. Ross and K. Murakawa, *J. Phys. Soc. Japan* 19, 249 to 253 (1964).
hfs
- Yu. Chaiko, *Opt. i Spektr.* 20, 760 to 767 (1966). I S
- W. F. Meggers and C. H. Corliss, *J. Research Nat. Bur. Std.* 70A, 63 to 106 (1966). W L, Z E
- J. Reader and J. Sugar, *J. Opt. Soc. Am.* 56, 1189 to 1194 (1966). I P
- B. Budick and J. Snir, *Phys. Lett. (Amsterdam)* A24, 689 to 690 (1967).
Z E Atomic Beam
- B. Budick and J. Snir, *Phys. Lett. (Amsterdam)* B24, 276 to 277 (1967).
hfs
- A. C. Parr and F. A. Elder, *J. Chem. Phys.* 49, 2665 to 2667 (1968).
Series I P
- W. F. Meggers, Monograph in course of preparation by C. E. Moore (1969).
T, C L, Z E

YTTERBIUM

Yb II

- A. S. King, *Astroph. J.* 74, 328 to 335 (1931). Temperature Classification
- W. F. Meggers and B. F. Scribner, *J. Research Nat. Bur. Std.* 19, 651 to 664, RP1053 (1938). T, C L, W L
- W. F. Meggers, *J. Opt. Soc. Am.* 37, 988 to 989 (A) (1947). T, C L, Z E
- G. Racah, *Bull. Research Council Israel* 3, 437 (A) (1954). Theory
- D. Sperber, *Bull. Research Council Israel* 3, 437 (A) (1954). Theory
- G. Racah, unpublished material (1955). Theory
- K. Krebs and H. Nelkowski, *Zeit. Phys.* 145, 543 to 559 (1956). I S, hfs
- C. J. Humphreys and E. Paul, Jr., *NAVORD Report* 5970, 57 to 67 (1959).
W L Near Infrared
- G. Racah, *J. Opt. Soc. Am.* 50, 408 to 411 (1960). T, E D, Theory
- L. Allen, United Kingdom, Atomic Energy Research Establishment AERE-R4029, 34 pp. (1962). Z E, W L
- J. Sugar, *J. Research Nat. Bur. Std.* 66A, 321 to 324 (1962). T
- W. F. Meggers, unpublished analysis (February 1963).
- J. S. Ross and K. Murakawa, *J. Phys. Soc. Japan* 19, 249 to 253 (1964).
hfs
- J. Sugar and J. Reader, *J. Opt. Soc. Am.* 55, 1286 to 1290 (1965). I P
- Yu. Chaiko, *Opt. i Spektr.* 20, 760 to 767 (1966). I S
- W. F. Meggers and C. H. Corliss, *J. Research Nat. Bur. Std.* 70A, 63 to 106 (1966). W L, Z E
- W. F. Meggers, *J. Research Nat. Bur. Std.* 71A, 396 to 544 (1967). I P,
T, C L, E D
- N. Spector, *J. Opt. Soc. Am.* 58, 837 to 842 (1968). Theory

YTTERBIUM

Yb III

- B. W. Bryant, Johns Hopkins Spectr. Report No. 21, 82 pp. (1961). T, C L, E D, W L, hfs, Stark Effect, Theory
- B. W. Bryant, J. Opt. Soc. Am. 55, 771 to 779 (1965). I P, T, C L, E D, Theory
- W. F. Meggers and C. H. Corliss, J. Research Nat. Bur. Std. 70A, 63 to 106 (1966). W L, Z E

Yb IV

- B. W. Bryant, Johns Hopkins Spectr. Report No. 21, 82 pp. (1961). T, C L, W L, Theory
- B. W. Bryant, J. Opt. Soc. Am. 55, 771 to 779 (1965). T, Theory
- W. F. Meggers and C. H. Corliss, J. Research Nat. Bur. Std. 70A, 63 to 106 (1966). W L

LUTETIUM (Z = 57)

Lu I

- W. F. Meggers and B. F. Scribner, Bur. Std. J. Research 5, 73 to 81, RP187 (1930). T, C L
- A. S. King, Astroph. J. 74, 336 to 341 (1931). Temperature Classification
- W. F. Meggers and B. F. Scribner, J. Research Nat. Bur. Std. 19, 31 to 39, RP1008 (1937). W L
- L. F. H. Bovey and W. R. S. Garton, Proc. Phys. Soc. (London) A67, 291 to 293 (1954). W L Absorption
- P. F. A. Klinkenberg, Physica 21, 53 to 62 (1954). I P, T, C L, G D
- L. F. H. Bovey, E. B. M. Steers and H. S. Wise, Proc. Phys. Soc. (London) A69, 783 to 784 (L) (1956). C L Infrared
- A. Steudel, Zeit. Phys. 152, 599 to 623 (1958). hfs, Z E

LUTETIUM

Lu I - Continued

- L. Bovey, Research (London) 13, 363 to 372, 428 to 435 (1960). G D, E D, C L
- L. Bovey, E. B. M. Steers and H. S. Wise, United Kingdom, Atomic Energy Research Establishment AERE-R3225, 8 pp. (1960). C L, W L
- J. Blaise, J. Bauche, S. Gerstenkorn et F. S. Tomkins, J. de Phys. 22, 417 to 427 (1961). hfs
- F. R. Petersen and H. A. Shugart, Phys. Rev. 126, 252 to 257 (1962). Z E, hfs
- G. J. Ritter, Phys. Rev. 126, 240 to 252 (1962). hfs, Z E
- U. Horstmann, G. Nöldeke und A. Steudel, Ann. der Phys. [7] 12, 14 to 19 (1963). hfs, T
- E. H. Pinnington, Can. J. Phys. 41, 1294 to 1304 (1963). Z E, W L, hfs, T

Lu II

- W. F. Meggers and B. F. Scribner, Bur. Std. J. Research 5, 73 to 81, RP187 (1930). T, C L
- A. S. King, Astroph. J. 74, 336 to 341 (1931). Temperature Classification
- W. F. Meggers and B. F. Scribner, J. Research Nat. Bur. Std. 19, 31 to 39, RP1008 (1937). W L
- L. F. H. Bovey and R. W. B. Pearse, United Kingdom, Atomic Energy Research Establishment AERE C/R1976, 19 pp. (1956). I P, T, C L
- K. Murakawa, Phys. Rev. 110, 393 to 396 (1958). hfs
- A. Steudel, Zeit. Phys. 152, 599 to 623 (1958). hfs, Z E
- J. Blaise, J. Bauche, S. Gerstenkorn et F. S. Tomkins, J. de Phys. 22, 417 to 427 (1961). hfs
- E. H. Pinnington, Can. J. Phys. 41, 1305 to 1306 (1963). Z E, W L, T
- J. Sugar and J. Reader, J. Opt. Soc. Am. 55, 1286 to 1290 (1965). I P
- Z. B. Goldschmidt, Colloq. Intern. Centre Nat. Rech. Sci. (Paris) No.164, 365 to 384 (1967). Theory

LUTETIUM

Lu III

W. F. Meggers and B. F. Scribner, Bur. Std. J. Research 5, 73 to 81, RP187 (1930). T, C L

W. F. Meggers and B. F. Scribner, J. Research Nat. Bur. Std. 19, 31 to 39, RP1008 (1937). W L

A. Steudel, Zeit. Phys. 152, 599 to 623 (1958). hfs, Z E, T

K. Heilig und P. Kasten, Naturwiss. 54, 338 (1967). hfs

ACTINIUM (Z = 89)

Ac I

N. I. Kaliteevskii and A. N. Razumovskii, Atomnaya Energiya 3, 548 to 550 (1957). W L

W. F. Meggers, Spectrochim. Acta 10, 195 to 200 (1957). C L, W L

Ac II

N. I. Kaliteevskii and A. N. Razumovskii, Atomnaya Energiya 3, 548 to 550 (1957). W L

W. F. Meggers, Spectrochim. Acta 10, 195 to 200 (1957). C L, W L

Ac III

N. I. Kaliteevskii and A. N. Razumovskii, Atomnaya Energiya 3, 548 to 550 (1957). W L

W. F. Meggers, Spectrochim. Acta 10, 195 to 200 (1957). C L, W L

Ac IV

W. F. Meggers, Spectrochim. Acta 10, 195 to 200 (1957). W L?

THORIUM (Z = 90)

Th I

- M. Fred, *Astroph. J.* 87, 176 to 197 (1938). W L, Z E
- C. Moore-Sitterly and A. S. King, *Proc. Am. Phil. Soc.* 86, 339 to 341 (1943). W L
- J. R. McNally, *J. Opt. Soc. Am.* 35, 390 to 398 (1945). W L Infrared
- PH. Schuurmans, Dissertation, Univ. Amsterdam, pp. 62 to 65 (N. V. Noord-Hollandsche Uitgevers Maatschappij, Amsterdam) (1946). T, Z E
- G. L. Stukenbroeker and J. R. McNally, Jr., *J. Opt. Soc. Am.* 43, 36 to 41 (1953). I S, T, C L
- G. W. Charles, Oak Ridge Nat. Lab. ORNL-2319, 143 to 159 (1958). T, C L, Z E, I S
- W. F. Meggers and R. W. Stanley, *J. Research Nat. Bur. Std.* 61, 95 to 103, RP2891 (1958). Interf. W L, Intervals
- R. Zalubas, *J. Research Nat. Bur. Std.* 63A, 275 to 278 (1959). T, C L, Z E
- R. E. Trees, *Physica* 26, 353 to 360 (1960). Theory Z E
- E. A. Vernyi a V. N. Egorov, *Opt. i Spektr.* 9, 692 to 702 (1960). I S, T
- R. Zalubas, *Nat. Bur. Std. Monograph* 17, 103 pp. (1960). W L
- B. Edlén, *Trans. Intern. Astron. Union* 11A, 105 to 108 (1961); 12A, 137 to 143 (1964). W L Standards
- A. Davison, A. Giacchetti and R. W. Stanley, *J. Opt. Soc. Am.* 52, 447 to 451 (1962). Interf. W L
- G. W. Charles, *J. Opt. Soc. Am.* 54, 267 to 268 (L) (1964). I S, T, W L
- V. N. Egorov, *Opt. i Spektr.* 16, 549 to 554 (1964). hfs
- A. Giacchetti, M. Gallardo, M. J. Garavaglia, Z. Gonzalez, F. P. J. Valero and E. Zakowicz, *J. Opt. Soc. Am.* 54, 957 to 959 (L)(1964). Interf. W L
- T. A. Littlefield and A. Wood, *J. Opt. Soc. Am.* 55, 1509 to 1516 (1965). Interf. W L, Intervals
- W. F. Meggers and R. W. Stanley, *J. Research Nat. Bur. Std.* 69A, 109 to 118 (1965). Interf. W L, Intervals
- A. Giacchetti, Argonne Nat. Lab. ANL-7209, 26 pp. (1966). Interf. W L

THORIUM

Th I - Continued

- E. B. M. Steers, Spectrochim. Acta 23B, 135 to 166 (1967). T, C L, W L
1 μ to 2.5 μ
- F. P. J. Valero, J. Opt. Soc. Am. 58, 484 to 489, 1048 to 1053 (1968).
T, C L, Interf. W L, Intervals
- M. Wilson, J. Opt. Soc. Am. 58, 1404 to 1405 (1968). Theory
- R. Zalubas, J. Opt. Soc. Am. 58, 1195 to 1199 (1968). T, Z E
- R. Zalubas, unpublished material (1969). T, C L, Z E, W L

Th II

- M. Fred, Astroph. J. 87, 176 to 197 (1938). W L
- C. Moore-Sitterly and A. S. King, Proc. Am. Phil. Soc. 86, 339 to 341
(1943). W L, C L, Solar data
- T. L. de Bruin, P. F. A. Klinkenberg and PH. Schuurmans, Zeit. Phys. 122,
23 to 35 (1944). T, C L, Z E
- J. R. McNally, Jr., J. Opt. Soc. Am. 35, 390 to 398 (1945). T, C L, Z E,
W L Infrared
- P. F. A. Klinkenberg, Physica 12, 33 to 48 (1946). C L, Z E
- PH. Schuurmans, Dissertation, Univ. Amsterdam, pp. 49 to 62 (N. V. Noord-
Hollandsche Uitgevers Maatschappij, Amsterdam) (1946). T, C L, Z E, E D
- D. Kessler, Physica 17, 913 to 919 (1951). Theory T, Z E
- Y. Eisenberg, Physica 18, 177 to 181 (1952). Theory T, Z E
- G. L. Stukenbroeker and J. R. McNally, Jr., J. Opt. Soc. Am. 43, 36 to 41
(1953). I S, T, C L
- G. W. Charles, Oak Ridge Nat. Lab. ORNL-2319, 23 to 142, 153 to 159
(1958). T, C L, Z E, I S
- W. F. Meggers and R. W. Stanley, J. Research Nat. Bur. Std. 61, 95 to
103, RP2891 (1958). Interf. W L, Intervals
- J. B. Ganz, Bull. Research Council Israel 9F, 31 to 42 (1960). Theory
T, Z E

THORIUM

Th II - Continued

- E. A. Vernyi a V. N. Egorov, Opt. i Spektr. 9, 692 to 702 (1960). I S, T
- R. Zalubas, Nat. Bur. Std. Monograph 17, 103 pp. (1960). W L
- B. Edlén, Trans. Intern. Astron. Union 11A, 105 to 108 (1961); 12A, 137 to 143 (1964). W L Standards
- A. Davison, A. Giacchetti and R. W. Stanley, J. Opt. Soc. Am. 52, 447 to 451 (1962). Interf. W L
- G. W. Charles, J. Opt. Soc. Am. 54, 267 to 268 (L) (1964). I S, T, W L
- V. N. Egorov, Opt. i Spektr. 16, 549 to 554 (1964). hfs
- A. Giacchetti, M. Gallardo, M. J. Garavaglia, Z. Gonzalez, F. P. J. Valero and E. Zakowicz, J. Opt. Soc. Am. 54, 957 to 959 (L)(1964). Interf. W L
- T. A. Littlefield and A. Wood, J. Opt. Soc. Am. 55, 1509 to 1516 (1965). Interf. W L, Intervals
- W. F. Meggers and R. W. Stanley, J. Research Nat. Bur. Std. 69A, 109 to 118 (1965). Interf. W L, Intervals
- A. Giacchetti, Argonne Nat. Lab. ANL-7209, 26 pp. (1966). Interf. W L
- E. B. M. Steers, Spectrochim. Acta 23B, 135 to 166 (1967). T, C L, W L 1μ to 2.5μ
- J. Blaise und A. Steudel, Zeit. Phys. 209, 311 to 328 (1968). I S
- F. P. J. Valero, J. Opt. Soc. Am. 58, 484 to 489 (1968). Interf. W L

Th III

- R. J. Lang, Phys. Rev. 71, 907 (L) (1947). T
- P. F. A. Klinkenberg, Physica 16, 618 to 650 (1950). I P, T, C L, Z E, E D, Stark Effect
- G. Racah, Physica 16, 651 to 666 (1950). Theory T, Z E
- G. W. Charles, Oak Ridge Nat. Lab. ORNL-2319, 7 to 23 (1958). I P, T, C L, Z E
- R. Zalubas, Nat. Bur. Std. Monograph 17, 103 pp. (1960). W L

THORIUM

Th IV

P. F. A. Klinkenberg and R. J. Lang, Physica 15, 774 to 788 (1949). I P, T, C L, Z E, G D

P. F. A. Klinkenberg, Physica 16, 185 to 197 (1950). T, C L, Z E, G D

G. W. Charles, Oak Ridge Nat. Lab. ORNL-2319, 5 to 6 (1958). I P, T, C L, Z E

R. Zalubas, Nat. Bur. Std. Monograph 17, 103 pp. (1960). W L

PROTACTINIUM (Z = 91)

Pa I

F. S. Tomkins and M. Fred, J. Opt. Soc. Am. 39, 357 to 363 (1949). W L

J. C. Hubbs and J. Winocur, Bull. Am. Phys. Soc. [2] 3, 319 (1958). hfs, Z E

B. R. Judd, Phys. Rev. 125, 613 to 625 (1962). Theory T, Z E

E. W. T. Richards and N. J. Atherton, United Kingdom, Atomic Energy Research Establishment, AERE-R3851, 18 pp. (1962). W L, hfs 0.8μ to 3.0μ

A. Giacchetti, J. Opt. Soc. Am. 56, 653 to 657 (1966). T, Z E

M. Wilson, J. Opt. Soc. Am. 57, 429 to 430 (L) (1967). Theory

Pa II

A. Giacchetti, J. Opt. Soc. Am. 57, 728 to 733 (1967). T, C L, E D, hfs

M. Wilson, J. Opt. Soc. Am. 57, 429 to 430 (L) (1967). Theory

Pa III

M. Wilson, J. Opt. Soc. Am. 57, 429 to 430 (L) (1967). Theory

URANIUM (Z = 92)

U I

- C. C. Kiess, C. J. Humphreys and D. D. Laun, J. Research Nat. Bur. Std. 37, 1 to 16, RP1729 (1946). I P, T, C L, Z E
- PH. Schuurmans, J. C. van den Bosch and N. Dijkwel, Physica 13, 117 to 140 (1947). T, Z E
- J. C. van den Bosch and G. J. van den Berg, Physica 15, 329 to 350 (1949). Z E, T, W L
- J. R. McNally, Jr., J. Opt. Soc. Am. 39, 271 to 274 (1949). I S
- L. A. Korostyleva, A. R. Striganov a N. M. Yashkin, Zh. Eks. Teor. Fiz., U.S.S.R. 28, 471 to 479 (1955). hfs, C L
- A. R. Striganov a L. A. Korostyleva, Zh. Eks. Teor. Fiz., U.S.S.R. 29, 393 to 405 (1955). I S
- N. I. Kaliteevski a M. P. Chaika, Opt. i Spektr. 1, 809 to 811 (1956). hfs
- N. P. Penkin a S. E. Frisch, Opt. i Spektr. 3, 473 to 479 (1957). T, C L, W L Emission, Absorption
- L. Bovey and H. Wise, United Kingdom, Atomic Energy Research Establishment AERE C/R2766, 199 pp. (1959). W L Emission, Absorption
- L. A. Korostyleva a A. R. Striganov, Opt. i Spektr. 7, 137 to 140 (1959). I S, C L, W L
- E. W. T. Richards and M. D. Crew, United Kingdom, Atomic Energy Research Establishment AERE-R2941, 202 pp. (1959). W L, C L, I S
- N. Atherton and L. Bovey, United Kingdom, Atomic Energy Research Establishment AERE-R3226, 24 pp. (1960). W L, C L, I S 1μ to 2.5μ
- R. Beer and L. Bovey, Proc. Phys. Soc. (London) 76, 569 to 574 (1960). hfs, I S 1.6μ to 2.1μ
- L. Bovey, N. Atherton, R. Beer and J. Ring, United Kingdom, Atomic Energy Research Establishment AERE-R3398, 13 pp. (1960). Wave Number, I S, hfs 1μ to 3μ
- M. Diringer, Compt. Rend. 250, 828 to 833 (1960). I S, C L
- E. A. Vernyi a V. N. Egorov, Opt. i Spektr. 9, 692 to 702 (1960). I S
- L. Bovey, N. Atherton and E. B. M. Steers, Spectrochim. Acta 17, 259 to 278 (1961). W L, C L, I S 1μ to 2.5μ

URANIUM

U I - Continued

- J. Blaise and M. Diringer, unpublished material (July 1962). T, I S
- B. R. Judd, Phys. Rev. 125, 613 to 625 (1962). Theory T, Z E, E D
- S. Held, Israel Atomic Energy Commission Report 1A-841, 1 to 38 (1963).
W L
- P. R. Rao, Indian Acad. Sci. A58, 353 to 361 (1963). I S, T, C L
- E. W. T. Richards, N. J. Atherton and E. B. M. Steers, United Kingdom,
Atomic Energy Research Establishment AERE-R3788, 37 pp. (1963). W L,
I S 0.8 μ to 2.5 μ
- J. M. Gagné, S. Gerstenkorn et J. M. Helbert, Compt. Rend. 259, 3479 to
3482 (1964). I S, C L
- M. Diringer, Ann. de Phys. [13] 10, 89 to 120 (1965). I S, T, C L,
Theory
- J.-M. Gagné, Can. J. Phys. 44, 423 to 429 (1966). I S, C L
- D. D. Laun, J. Research Nat. Bur. Std. 70A, 323 to 324 (1966). T, C L
- B. Osman, Thèse, Univ. Paris, 124 pp. (1966). T, C L, Z E, I S
- D. W. Steinhaus, J. Blaise and M. Diringer, Los Alamos Sci. Lab.
LA-3475, 187 pp. (1966). T, C L, I S
- J. Blaise und A. Steudel, Zeit. Phys. 209, 311 to 328 (1968). I S
- B. R. Judd, J. Opt. Soc. Am. 58, 1311 to 1312 (L) (1968). E D, Theory

U II

- PH. Schuurmans, Dissertation, Univ. Amsterdam, pp. 66 to 73 (N. V. Noord-
Hollandsche Uitgevers Maatschappij, Amsterdam) (1946). T, Z E
- PH. Schuurmans, Physica 11, 419 to 425 (1946). T, Z E
- PH. Schuurmans, J. C. van den Bosch and N. Dijkwel, Physica 13, 117 to
140 (1947). T, C L, Z E, W L
- J. C. van den Bosch, Physica 15, 503 to 522 (1949). T, C L

URANIUM

U II - Continued

- J. C. van den Bosch and G. J. van den Berg, *Physica* 15, 329 to 350 (1949).
Z E, T, W L
- L. E. Burkhart, G. Stukenbroeker and S. Adams, *Phys. Rev.* 75, 83 to 85
(1949). I S
- J. R. McNally, Jr., *J. Opt. Soc. Am.* 39, 271 to 274 (1949). I S
- J. C. van den Bosch, *Phys. Rev.* 80, 100 (L) (1950). T
- J. R. McNally, Jr., *Phys. Rev.* 77, 417 to 418 (L) (1950). T
- D. D. Smith, G. L. Stukenbroeker and J. R. McNally, Jr., *Phys. Rev.* 84,
383 to 384 (L) (1951). I S
- L. A. Korostyleva, A. R. Striganov a N. M. Yashkin, *Zh. Eks. Teor. Fiz.*,
U.S.S.R. 28, 471 to 479 (1955). hfs, C L
- A. R. Striganov a L. A. Korostyleva, *Zh. Eks. Teor. Fiz.*, U.S.S.R. 29,
393 to 405 (1955). I S, C L
- L. Bovey and H. Wise, United Kingdom, Atomic Energy Research Establish-
ment AERE C/R2766, 199 pp. (1959). W L Emission, Absorption
- L. A. Korostyleva a G. A. Striganova, *Opt. i Spektr.* 7, 137 to 140 (1959).
I S, W L, C L
- E. W. T. Richards and M. D. Crew, United Kingdom, Atomic Energy Research
Establishment AERE-R2941, 202 pp. (1959). W L, I S
- D. W. Steinhaus, *J. Opt. Soc. Am.* 50, 672 to 675 (1960). T
- F. A. Vernyi a V. N. Egorov, *Opt. i Spektr.* 9, 692 to 702 (1960). I S
- J. Sugar, *J. Research Nat. Bur. Std.* 66A, 321 to 324; and unpublished
material (1962). T
- S. Held, Israel Atomic Energy Commission Report 1A-841, 1 to 30, 39
(1963). W L
- M. Diringier, *Ann. de Phys.* [13] 10, 89 to 120 (1965). I S, T, C L,
Theory
- B. Osman, These, Univ. Paris, 124 pp. (1966). T, C L, Z E, I S
- J. Blaise, *Colloq. de Sp. At.*, Caen (October 1968). T, C L, Z E
- J. Blaise und A. Steudel, *Zeit. Phys.* 209, 311 to 328 (1968). I S

URANIUM

U IV

H. M. Crosswhite, NASA Doc. N63-17609, 35 pp. (1963). Theory $5f^3$ Configuration

U VI

P. F. A. Klinkenberg, Physica 16, 185 to 197 (1950). T Theory

NEPTUNIUM (Z = 93)

Np I

F. S. Tomkins and M. Fred, J. Opt. Soc. Am. 39, 357 to 363 (1949). W L

J. C. Hubbs and R. Marrus, Phys. Rev. 110, 287 to 289 (L) (1958). hfs,
Z E Atomic Beam

L. Bovey, E. B. M. Steers and N. Atherton, United Kingdom, Atomic Energy Research Establishment AERE-R2977 (1959). W L 1μ to 3μ

L. Bovey and E. B. M. Steers, United Kingdom, Atomic Energy Research Establishment AERE-R3118, 5 pp. (1959). W L 1μ to 3μ

B. R. Judd, Phys. Rev. 125, 613 to 625 (1962). Theory T, Z E

M. Fred and F. S. Tomkins, J. Opt. Soc. Am. 53, 506 (A) (1963). Analysis in progress

G. Smith, J. Opt. Soc. Am. 54, 565 (A) (1964). Z E, hfs

PLUTONIUM (Z = 94)

Pu I

F. S. Tomkins and M. Fred, J. Opt. Soc. Am. 39, 357 to 363 (1949). W L

M. van den Berg and P. F. A. Klinkenberg, Physica 20, 461 to 480 (1954). W L, hfs

PLUTONIUM

Pu 1 - Continued

- J. G. Conway, J. Opt. Soc. Am. 44, 276 to 278 (1954). W L Furnace Spectrum
- L. Bovey, Spectrochim. Acta 10, 383 to 394 (1958). W L Emission and Absorption
- J. C. Hubbs, R. Marrus, W. A. Nierenberg and J. W. Worchester, Phys. Rev. 109, 390 to 398 (1958). hfs, Z E Atomic Beam
- L. Bovey, N. Atherton, R. Beer and J. Ring, United Kingdom, Atomic Energy Research Establishment AERE-R3398, 13 pp. (1960). Wave Number, I S 1μ to 3μ
- L. Bovey and H. Ridgeley, United Kingdom, Atomic Energy Research Establishment AERE-R3393, 13 pp. (1960). Z E, T, C L, hfs, I S
- L. Bovey and E. B. M. Steers, Spectrochim. Acta 16, 1184 to 1199 (1960). W L 1μ to 2.5μ
- S. Gerstenkorn, Compt. Rend. 250, 825 to 827 (1960). hfs
- J. R. McNally, Jr., Oak Ridge Nat. Lab. ORNL-2154 Revised, 207 pp. (1960). W L
- L. Bovey and S. Gerstenkorn, J. Opt. Soc. Am. 51, 522 to 525 (1961). T, Z E, W L, Intervals, hfs, I S
- J. Blaise, M. Fred, S. Gerstenkorn et B. R. Judd, Compt. Rend. 255, 2403 to 2405 (1962). T, Z E, hfs, I S Ground Term
- S. Gerstenkorn, Thèse, Ann. de Phys. [13] 7, 367 to 404, 405 to 414 (1962). T, C L, W L, hfs, I S
- E. W. T. Richards, N. J. Atherton and E. B. M. Steers, United Kingdom, Atomic Energy Research Establishment AERE-R3788, 37 pp. (1963). W L, I S 0.8μ to 2.5μ
- J. Bauche, J. Blaise and M. Fred, J. Opt. Soc. Am. 54, 565A (1964). I P, T, C L, Z E, W L, I S, hfs
- J. Bauche and B. Judd, Proc. Phys. Soc. (London) 83, 145 to 156 (1964). hfs Theory
- L. A. Korostyleva, Opt. i Spektr. 17, 469 to 474 (1964). W L
- E. W. T. Richards and A. Ridgeley, Spectrochim. Acta 21, 1449 to 1466 (1965). T, C L, Z E, I S, hfs

PLUTONIUM

Pu I - Continued

- M. Fred, J. Blaise and R. Gutmacher, J. Opt. Soc. Am. 56, 1416A (1966).
T, C L, Z E, W L, I S, hfs
- L. A. Korostyleva and A. R. Striganov., Opt. i Spektr. 20, 545 to 553
(1966). hfs, I S, W L, C L, G D
- F. Tomkins et S. Gerstenkorn, Compt. Rend. 265B, 1311 to 1313 (1967). I S
- J. Blaise and A. Steudel, Zeit. Phys. 209, 311 to 328 (1968). I S

Pu II

- M. van den Berg and P. F. A. Klinkenberg, Physica 20, 461 to 480 (1954).
W L, hfs
- J. G. Conway, J. Opt. Soc. Am. 44, 276 to 278 (1954). W L? Furnace
Spectrum
- P. M. Griffin and J. R. McNally, Jr., J. Opt. Soc. Am. 45, 63 (L) (1955).
Z E
- J. Haaland, Joint Est. Nuclear Energy Research, JENER Report No. 51,
19 pp. (1957); See Chem. Abstr. 52, 1753i (1958). W L
- L. Bovey, Spectrochim. Acta 10, 383 to 394 (1958). W L Emission and
Absorption
- J. R. McNally, Jr. and P. M. Griffin, J. Opt. Soc. Am. 49, 162 to 166
(1959). T, Z E
- J. H. Wise, Bull. Am. Phys. Soc. [2] 4, 262 (1959). T, Z E
- J. R. McNally, Jr., Oak Ridge Nat. Lab. ORNL-2154 Revised, 207 pp. (1960).
W L
- S. Gerstenkorn, Ann. de Phys. [13] 7, 397, 405 to 414 (1962). hfs, C L
- B. R. Judd, Phys. Rev. 125, 613 to 625 (1962). Theory T, Z E
- L. A. Korostyleva, Opt. i Spektr. 12, 671 to 676 (1962). hfs, W L
- J. Bauche, J. Blaise et M. Fred, Compt. Rend. 256, 5091 to 5093 (1963).
T, Z E

PLUTONIUM

Pu II - Continued

J. Bauche, J. Blaise and M. Fred, J. Opt. Soc. Am. 54, 565A (1964). T, C L, W L, Z E, I S, hfs

R.-J. Champeau, J. de Phys. 25, 825 to 830 (1964). hfs

L. A. Korostyleva, Opt. i Spektr. 17, 469 to 474 (1964). W L

M. Fred, J. Blaise and R. Gutmacher, J. Opt. Soc. Am. 56, 1416A (1966). T, C L, W L, Z E, I S, hfs

L. A. Korostyleva a A. R. Striganov, Opt. i Spektr. 20, 194 to 196, 545 to 553 (1966). hfs, I S, W L, C L

J. Blaise und A. Steudel, Zeit. Phys. 209, 311 to 328 (1968). I S

Pu IV

B. G. Wybourne, J. Chem. Phys. 36, 2301 to 2311 (1962). Theory, fⁿ Terms

AMERICIUM (Z = 95)

Am I

F. S. Tomkins and M. Fred, J. Opt. Soc. Am. 39, 357 to 363 (1949). W L

J. G. Conway and R. D. McLaughlin, Phys. Rev. 94, 498 (L) (1954). I S, W L

M. N. Oganov, A. P. Striganov a Yu. P. Sobolev, Opt. i Spektr. 1, 965 to 971 (1956). W L

M. Fred and F. S. Tomkins, J. Opt. Soc. Am. 47, 1076 to 1087 (1957). I P, T, C L, hfs, I S

R. Beer and I. Bovey, Proc. Phys. Soc. (London) 76, 569 to 574 (1960). hfs, I S 1.6 μ to 2.1 μ

AMERICIUM

Am I - Continued

- L. Bovey, N. Atherton, R. Beer and J. Ring, United Kingdom, Atomic Energy Research Establishment AERE-R3398, 13 pp. (1960). Wave Number, C L, hfs
- R. Marrus, W. A. Nierenberg and J. Winocur, Phys. Rev. 120, 1429 to 1435 (1960). hfs, Z E Atomic Beam
- K. Krebs und R. Winkler, Zeit. Phys. 162, 235 to 244 (1961). T, hfs
- J. Bauche and B. R. Judd, Proc. Phys. Soc. (London) 83, 145 to 156 (1964). hfs Theory
- G. Smith, J. Opt. Soc. Am. 55, 937 to 939 (1965). Z E, hfs
- L. Armstrong, Jr. and R. Marrus, Phys. Rev. 144, 994 to 998 (1966). hfs, Z E Atomic Beam
- J. Blaise und A. Steudel, Zeit. Phys. 209, 311 to 328 (1968). I S

Am II

- R. P. Thorne, Spectrochim. Acta 8, 71 to 87 (1956). W L, hfs
- M. Fred and F. S. Tomkins, J. Opt. Soc. Am. 47, 1076 to 1087 (1957). T, C L, hfs, I S
- L. Bovey, Research (London) 13, 433 (1960). hfs
- G. Smith, J. Opt. Soc. Am. 54, 565 (A) (1964). Z E, hfs
- R. Winkler, Zeit. Phys. 184, 433 to 450 (1965). hfs
- J. Blaise und A. Steudel, Zeit. Phys. 209, 311 to 328 (1968). I S

Am III

- R. Winkler, Zeit. Phys. 184, 433 to 450 (1965). hfs

AMERICIUM

Am IV

- J. B. Gruber and J. G. Conway, J. Chem. Phys. 34, 632 to 638 (1961). T
f⁶ Configuration Theory
- S. Gerstenkorn, Ann. de Phys. [13] 7, 393 (1962). E D
- W. T. Carnell, P. R. Fields and B. G. Wybourne, J. Chem. Phys. 41, 2195
to 2196 (L) (1964). Theory
- J. G. Conway and B. R. Judd, J. Chem. Phys. 41, 1526 (L) (1964). Theory

CURIUM (Z = 96)

Cm I

- J. G. Conway, M. F. Moore and W. W. T. Crane, J. Am. Chem. Soc. 73, 1308
to 1309 (1951). W L
- J. G. Conway and R. D. McLaughlin, J. Opt. Soc. Am. 46, 91 to 93 (1956).
I S, W L
- J. C. Hubbs, R. Marrus and J. Winocur, Phys. Rev. 114, 586 to 589 (1959).
Z E
- B. R. Judd, Phys. Rev. 125, 613 to 625 (1962). Theory T, Z E
- E. F. Worden, R. G. Gutmacher, E. K. Hulet, J. G. Conway and M. Fred,
J. Opt. Soc. Am. 52, 1311 (A) (1962). Ground Term, Z E
- J. G. Conway, unpublished material (1966); Program Atomic Sp. Symposium,
Nat. Bur. Std., p. 17 (1967). T, C L, W L, Z E, I S

Cm II

- J. G. Conway, M. F. Moore and W. W. T. Crane, J. Am. Chem. Soc. 73, 1308
to 1309 (1951). W L
- J. G. Conway, unpublished material (1966); Program Atomic Sp. Symposium,
Nat. Bur. Std., p. 17 (1967). T, C L, W L, Z E, I S
- E. F. Worden and J. G. Conway, Physica 33, 274 (A) (1967). Ground Term,
Z E

CURIUM

Cm IV

B. G. Wybourne, J. Chem. Phys. 40, 1456 to 1457 (L) (1964). Theory

BERKELIUM (Z = 97)

Bk I

B. R. Judd, Phys. Rev. 125, 613 to 625 (1962). Theory T, Z E

E. F. Worden, E. K. Hulet, R. Lougheed and J. G. Conway, J. Opt. Soc. Am. 57, 550 (L) (1967). hfs

Bk II

R. G. Gutmacher, E. K. Hulet and R. Lougheed, J. Opt. Soc. Am. 55, 1029 to 1030 (L) (1965). Sensitive Spark Lines

E. F. Worden, E. K. Hulet, R. Lougheed and J. G. Conway, J. Opt. Soc. Am. 57, 550 (L) (1967). hfs

CALIFORNIUM (Z = 98)

Cf I

J. G. Conway, E. K. Hulet and R. J. Morrow, J. Opt. Soc. Am. 52, 222 (L) (1962). W L

Cf IV

B. G. Wybourne, J. Chem. Phys. 36, 2301 to 2311 (1962). Theory, f^n Terms

EINSTEINIUM ($Z = 99$)

Es I

B. R. Judd, Phys. Rev. 125, 613 to 625 (1962). Theory T, Z E

E. F. Worden, R. G. Gutmacher, R. W. Loughheed, J. E. Evans and J. G. Conway, J. Opt. Soc. Am. 58, 998 to 1000 (L) (1968). W L, hfs

Es II

R. G. Gutmacher, J. E. Evans and E. K. Hulet, J. Opt. Soc. Am. 57, 1389 to 1390 (L) (1967). Sensitive Spark Lines, hfs

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